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Transmitted herewith for filing is the patent application of

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For : VIDEO CODER EMPLOYING PIXEL TRANSPOSITION

Enclosed are:

1. 8 sheets of specification, 5 sheets of claims, and 1 sheet of abstract.
2. 3 sheets of drawings.
3. Assignment Transmittal w/Assignment
4. Declaration and Power of Attorney

The filing fee has been calculated as shown below:

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BASIC FEE			0.00	790.00
TOTAL CLAIMS	28 - 20 =	8	22.00	176.00
INDEPENDENT CLAIMS	5 - 3 =	2	82.00	164.00
MULTIPLE DEPENDENT CLAIM PRESENT				
FEE FOR RECORDATION OF ASSIGNMENT				40.00
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3. The Office is authorized to charge the filing fee of $1,170.00 to AT&T Corporate Deposit Account No. 1-2745. A duplicate copy of this paper is enclosed for that purpose.

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VIDEO CODER EMPLOYING PIXEL TRANSPOSITION

BACKGROUND OF THE INVENTION

The present invention relates to block based video coding schemes and, most particularly, to a method of eliminating artifacts at block boundaries by transposing pixels at block boundaries with pixels from boundaries of neighboring blocks before coding.

Known systems for coding video information advantageously employ transform coding of a plurality of blocks or macro blocks. In such systems, image data often are filtered, broken down into a luminance component and two chrominance components, and organized into blocks of image data. For example, according to the proposed MPEG-4 video standard, image data are organized first into blocks, each containing an 8 pixel by 8 pixel array of data, then into macro blocks including up to four luminance blocks and two chrominance blocks. The blocks of image data are then transform coded from a pixel domain to an array of transform coefficients and scaled by a quantization parameter and transmitted in an output bit stream.

Block-based transform coding is preferred over other known coding schemes, such as wavelet coding, because it is relatively less complex to implement. However, such block-

based transform coding causes annoying artifacts in the reconstructed image. Quantization parameters may be established for each block or macro block of image data. Differences in quantization parameters among the various blocks or macro blocks result in distortion at the block boundaries. For instance, in flat image areas, such distortions impose a patchwork effect on reconstructed image data. Similar artifacts appear in image areas having heavy texture, but are less noticeable. Block based coding with variable quantization causes additional artifacts to arise, such as chromo-bleeding, "mosquito-noise" and "ringing" artifacts.

Prior systems have attempted to ameliorate the effect of such artifacts by low pass filtering reconstructed image data at block boundaries. However, while low pass filtering reduces block artifacts, it also causes blurring of image data. Low pass filtering impairs image quality.

There is a need in the art for an image coder that advantageously employs block-based transform coding and quantization but reduces image artifacts at block boundaries. Further, there is a need in the art for a coding scheme that reduces artifacts without unnecessarily blurring image data.

<u>SUMMARY OF THE INVENTION</u>

The disadvantages of the prior art are alleviated to a great extent by an image coding scheme that employs block-based transform coding and quantization. An encoder transposes pixels across block boundaries in a predetermined direction prior to transform coding. For example, alternate pixels along a boundary of a first block may be transposed with adjacent pixels in a diagonal direction of neighboring

blocks. After transposition, each reformed block undergoes transform coding and quantization.

A decoder performs reverse operations of those employed by the encoder. Each coded block is dequantized and coded by an inverse transform to reconstruct blocks of pixel information. At the conclusion of the inverse transform, pixels that were subject to transposition are returned to the neighboring blocks from which they originated. After transposition, each block may be processed further for display.

The pixel transposition reduces image artifacts at block boundaries and improves image quality, particularly in flat image areas. By including cross border pixels in the transform coding and quantization, the transform coding and quantization are performed with greater uniformity on image data.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1(a) and 1(b) respectively illustrate an encoder 100 and a decoder 200 according to an embodiment of the present invention.

Figs. 2(a) and 2(b) respectively illustrate the pixel transposition operation of the present invention as applied to blocks and macro blocks of image data.

DETAILED DESCRIPTION

Turning to Fig. 1(a), circuitry of an encoder 100 is illustrated therein constructed in accordance with an embodiment of the present invention. Blocks or macro blocks of image data are input to a pixel transposition circuit 110. Each block possesses one of luminance or chrominance image

data. The pixel transposition circuit 110 transposes specific pixels from the boundary of each block or macro block with pixels from its neighbors. The pixel transposition circuit 110 then outputs reconstituted blocks of pixel data to a transform coder 120. The transform coder 120 performs a transform of the block data from a pixel domain to a domain of coefficients representative of the pixel data. For example, the transform coder 120 may perform a discrete cosine transform as is known in the art. The transform coder 120 outputs blocks of coefficient data to a quantizer 130. For each block or macro block, the quantizer 130 generates a quantizer parameter (Q_p) based upon the bandwidth of a channel available to transmit the coded image data. The quantizer 130 scales the coefficients of the block by the quantization parameter. The quantizer 130 outputs blocks of scaled coefficient information and the quantization parameters generated for each for further processing and transmission.

Fig. 1(b) illustrates circuitry of a decoder 200 constructed in accordance with an embodiment of the present invention. Blocks of scaled coefficients are isolated from the transmitted bit stream and input to a dequantizer 230. The dequantizer 230 identifies the quantization parameter for each block and scales the scaled coefficients of the block by the quantization parameter. Where the quantizer 130 may have divided each coefficient by Qp, the dequantizer multiplies the scaled coefficients by the same Qp to obtain the original coefficients. The dequantizer 230 outputs reconstructed coefficient data to an inverse transform coding circuit 220. The inverse transform coding circuit 220 transforms the coefficients back to the pixel domain, such as by discrete

transform coding. The inverse transform coding circuit 220 outputs blocks or macro blocks of reconstructed pixel data to an inverse pixel transposition circuit 210. For each block or macro block, the inverse pixel transposition circuit 210 transposes pixels along its boundary with pixels of its neighbors in a direction complementary to the process applied by the pixel transposition circuit 110. The inverse pixel transposition circuit 210 returns pixels to their original position in the neighboring blocks or macro blocks. The inverse pixel transposition circuit 110 outputs blocks of pixel information for further processing and display.

An example of a pixel transposition process is shown in Fig. 2(a) applied on a block by block basis. For each block A, the pixel transposition circuit 110 stores, in memory, pixel information from a plurality of surrounding Blocks 1-8. The pixel transposition circuit 110 transposes pixel information in a predetermined direction. In the example of Fig. 2(a), the pixels are transposed along a diagonal direction from high-left to low-right and vice versa.

Under the pixel transposition process, each alternate pixel on the edge of a given block A is transposed with a pixel across the block boundary in the predetermined direction. In the example of Fig. 2(a), the pixel in the upper left-hand corner of block A is transposed with a pixel in the lower right-hand corner of block 1. Three pixels along the upper edge of block A are transposed with pixels on the lower edge of block 2 in the same diagonal direction. Alternate pixels found on the right-hand edge of block A are transposed with pixels on the left-hand edge of block 4 in the diagonal direction. The pixel in the lower right-hand corner of block A is transposed with a pixel in the upper

left-hand corner of block 5. Alternate pixels on the lower edge of block A are transposed with pixels on the upper edge of block 6 in the diagonal direction. Finally, alternate pixels on the left hand edge of block 8 are transposed with pixels found on the right-hand edge of block 8 in the diagonal direction.

Pixel transposition is performed only on like-kind data. When performing pixel transposition on a luminance block, the pixel transposition circuit 110 considers only neighboring luminance blocks for transposition. Similarly, for blocks of each of the two chrominance signals, pixel transposition is performed only with neighboring chrominance image blocks of the same type.

Fig. 2(b) illustrates an example where pixel transposition is performed on a macro block by macro block basis. In the event that the quantizer circuit 130 computes quantization parameters for each macro block rather than for each block, it is preferable to perform a pixel transposition on a macro block by macro block basis. In this example, a macro block consists of four blocks of image information, Blocks A-D. The macro block is surrounded by twelve neighboring blocks, Blocks 1-12. For the macro block, pixel transposition is performed on alternate pixels on the boundary of the macro block with pixel information of neighboring macro blocks along a pre-determined direction. In this example, the predetermined direction is from low-left to high-right and vice versa. As shown in Fig. 2(b), the pixel in the upper right-hand corner of Block B is transposed with a pixel in the lower left-hand corner of Block 4. Similarly, a pixel in a lower left-hand corner of Block C is transposed with a pixel in the upper right-hand corner of

Block 10. Alternate pixels on the top edge of the macro block, the top edges of Blocks A and B, are transposed with pixels on the bottom edges of Blocks 2 and 3 in a diagonal direction. Pixels on the right-hand edge of the macro block, the right-hand edges of Blocks B and D, are transformed on the left-hand edges of Blocks 5 and 6 in the diagonal direction. Blocks on the lower edge of the macro block, the lower edges of Blocks C and D, are transposed with pixels found in the diagonal direction on the upper edges of Blocks 8 and 9. Finally, pixels found on the left-hand edge of the macro block, the left-hand edges of Blocks A and C, are transposed with pixels found in a diagonal direction in the right-hand edges of Blocks 11 and 12.

The direction of transposition is arbitrary. Any direction may be applied. In addition to high-left to low-right and low-left to high-right, horizontal (right to left) and vertical (above to below) directions may be applied. The direction may be predetermined by the system or defined for each coded video frame. If the direction of transposition is variable, the pixel transposition circuit 110 includes a transposition keyword in the output bitstream identifying the direction of transposition. The decoder identifies the transposition keyword and identifies a directions of transposition therefrom.

So, too, the pattern of transposition may varied. In addition to selection of alternate pixels for transposition, every third or every fourth pixel may be selected for transposition. Further, the pattern may varied so as to select pixels at a first rate, such as every other pixel, in a first region of data, then a second rate, such as every fourth pixel, in a second region of data.

The encoder 100 and decoder 200 shown in Figs. 1(a) and 1(b) are not full video coders. Preprocessing is generally performed on pixels before they are input to the pixel transposition circuit 110, which generally involves sampling of image data, conversion to a digital format, filtering, and component isolation. Preprocessing also includes organization of the component signals into blocks. However, in a preferred embodiment, preprocessing functions may be merged into the pixel transposition circuit 110. In this case, the pixel transposition circuit may be programmed to reorder pixels before they are organized into blocks.

WE CLAIM:

1. A video coder, comprising:

a pixel transposition circuit that receives blocks of image data, each block including image data of an array of pixels, said pixel transposition circuit transposing selected pixels on a boundary of a first block with selected boundary pixels of a plurality of blocks neighboring said first block,

a transform circuit that generates coefficients representative of data of the transposed blocks, and

a quantizer that scales the coefficients.

2. The video coder of claim 1, wherein the pixel transposition circuit transposes alternate pixels along the boundary of said first block with pixels from the neighboring blocks adjacent to the alternate pixels in a transposition direction.

3. The video coder of claim 2 wherein the transposition direction is a diagonal direction, high-left to low-right.

4. The video coder of claim 2 wherein the transposition direction is a diagonal direction, low-left to high-right.

5. The video coder of claim 2, wherein the transposition direction is a vertical direction for pixels along a vertical edge of the first block and a horizontal direction for pixels along a horizontal edge of the first block.

6. A video decoder, comprising:

a dequantizer that receives blocks of scaled coefficient information and reconstructing coefficients therefrom,

an inverse transform circuit that reconstructs blocks of pixel data from the blocks of reconstructed coefficients, and

a pixel transposition circuit that transposes pixels on a boundary of a first block with boundary pixels of a plurality of blocks neighboring said first block and generating blocks of image data for display.

7. The video decoder of claim 6, wherein the pixel transposition circuit transposes alternate pixels along the boundary of the first block with pixels from the neighboring blocks adjacent to the alternate pixels in a transposition direction.

8. The video decoder of claim 7, wherein the transposition direction is a diagonal direction, high-left to low-right.

9. The video decoder of claim 7, wherein the transposition direction is a diagonal direction, low-left to high-right.

10. The video decoder of claim 7, wherein the transposition direction is a vertical direction for pixels along a vertical edge of the first block and a horizontal direction for pixels along a horizontal edge of the first block.

11. A method of encoding image data, comprising the steps of:

receiving blocks of image data, each block including data for an array of pixels,

transposing selected pixels on a boundary edge of a first block with selected pixels from a plurality of blocks neighboring said first block,

transforming pixel data of the blocks from the step transposing to coefficients, and

scaling the transformed blocks.

12. The method of claim 11, wherein the transposition step includes transposing alternate pixels along the boundary of the first block with pixels from the neighboring blocks adjacent to the alternate pixels in a transposition direction.

13. The method of claim 12, further comprising a step of generating a transposition keyword representative of the transposition direction.

14. The method of claim 12, wherein the transposition direction is a diagonal direction, high-left to low-right.

15. The method of claim 12, wherein the transposition direction is a diagonal direction, low-left to high-right.

16. The method of claim 12, wherein the transposition direction is a vertical direction for pixels along a vertical edge of the first block and a horizontal direction for pixels along a horizontal edge of the first block.

17. A method of decoding blocks of encoded image data, comprising the steps of:

scaling the coded blocks to obtain blocks of coefficient data,

transforming the coefficient data of the blocks to pixel data, and

transposing selected pixels on a boundary edge of a first block with selected pixels from a plurality of blocks neighboring said first block.

18. The method of claim 17, wherein the transposition step transposes alternate pixels along the boundary of the first block with pixels from the neighboring blocks adjacent to the alternate pixels in a transposition direction.

19. The method of claim 18, further comprising a step of receiving a transposition keyword that identifies a transposition direction.

20. The method of claim 18, wherein the transposition direction is a diagonal direction, high-left to low-right.

21. The method of claim 18, wherein the transposition direction is a diagonal direction, low-left to high-right.

22. The method of claim 18, wherein the transposition direction is a vertical direction for pixels along a vertical edge of the first block and a horizontal direction for pixels along a horizontal edge of the first block.

23. A bitstream generated by a process comprising the steps of:

receiving blocks of image data, each block including data for an array of pixels,

transposing selected pixels on a boundary edge of a first block with selected pixels from blocks neighboring the first block,

transforming pixel data of the transposed blocks to coefficients, and

scaling the transformed blocks.

24. The method of claim 23, wherein the transposition step includes a step of transposing alternate pixels along the boundary of the first block with pixels from the neighboring blocks adjacent to the alternate pixels in a transposition direction.

25. The method of claim 24, further comprising a step of generating a transposition keyword representative of the transposition direction.

26. The method of claim 24, wherein the transposition direction is a diagonal direction, high-left to low-right.

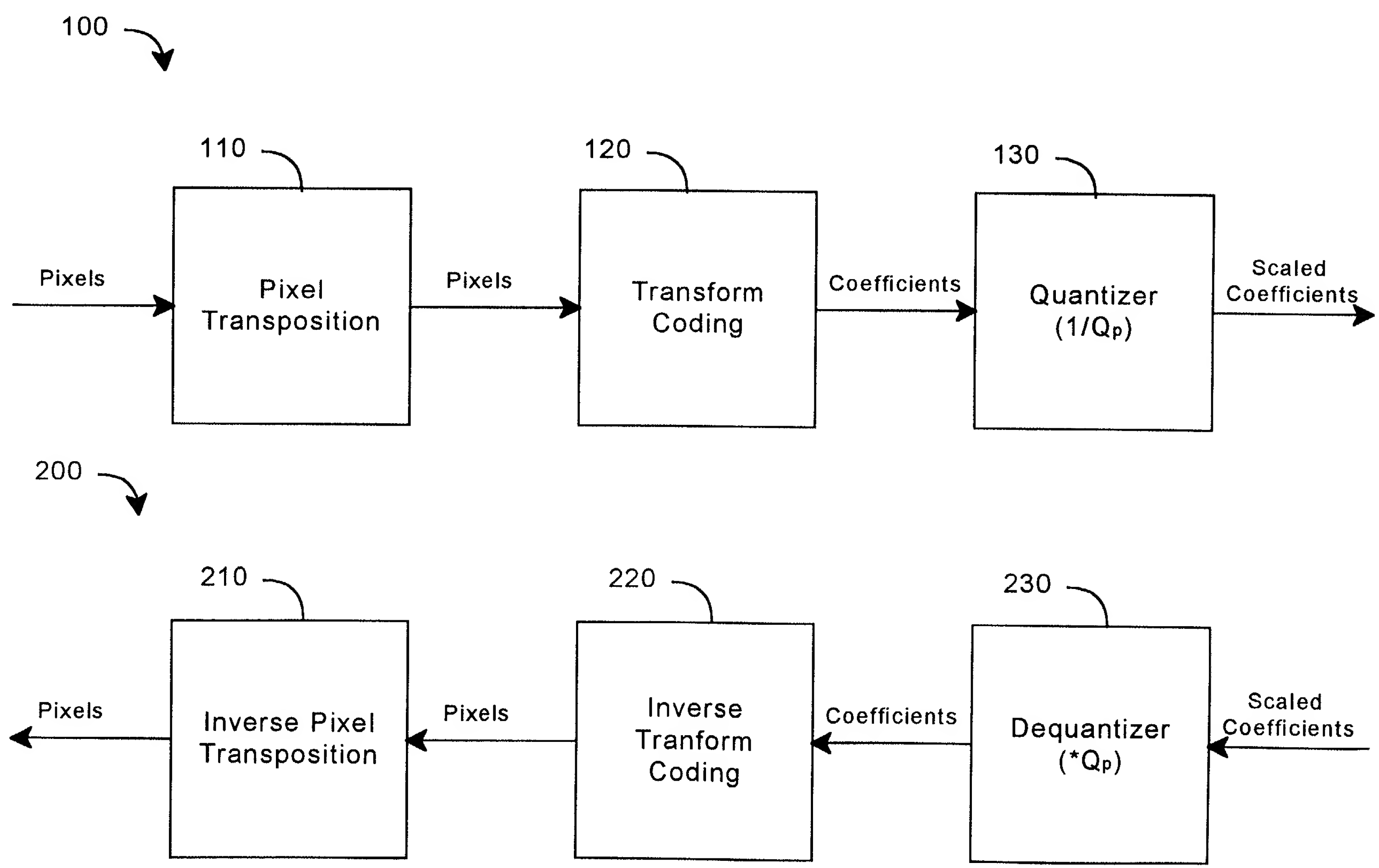
27. The method of claim 24, wherein the transposition direction is a diagonal direction, low-left to high-right.

28. The method of claim 24, wherein the transposition direction is a vertical direction for pixels along a vertical edge of the first block and a horizontal direction for pixels along a horizontal edge of the first block.

ABSTRACT OF THE DISCLOSURE

A video encoding method and apparatus is shown wherein image information is represented as a plurality of pixels, the pixels are organized into blocks, pixels transposition is performed on image information at the boundaries of the blocks, the blocks are transform coded and quantized. Pixel transposition involves transposition of alternate pixels at the boundaries of blocks with pixels of neighboring blocks found in a pre-determined direction. The pre-determined direction may be fixed by a system or may be applied on an image by image basis. In the event that the pre-determined direction is not established by a system, a pixel transposition circuit includes a transposition keyword in the output bit stream which is used by a decoded to determine the direction of pixel transposition.

FIG. 1



100
110
120
130
Pixels
Pixel Transposition
Pixels
Transform Coding
Coefficients
Quantizer (1/Qp)
Scaled Coefficients
200
210
220
230
Pixels
Inverse Pixel Transposition
Pixels
Inverse Tranform Coding
Coefficients
Dequantizer (*Qp)
Scaled Coefficients

FIG. 2(b)

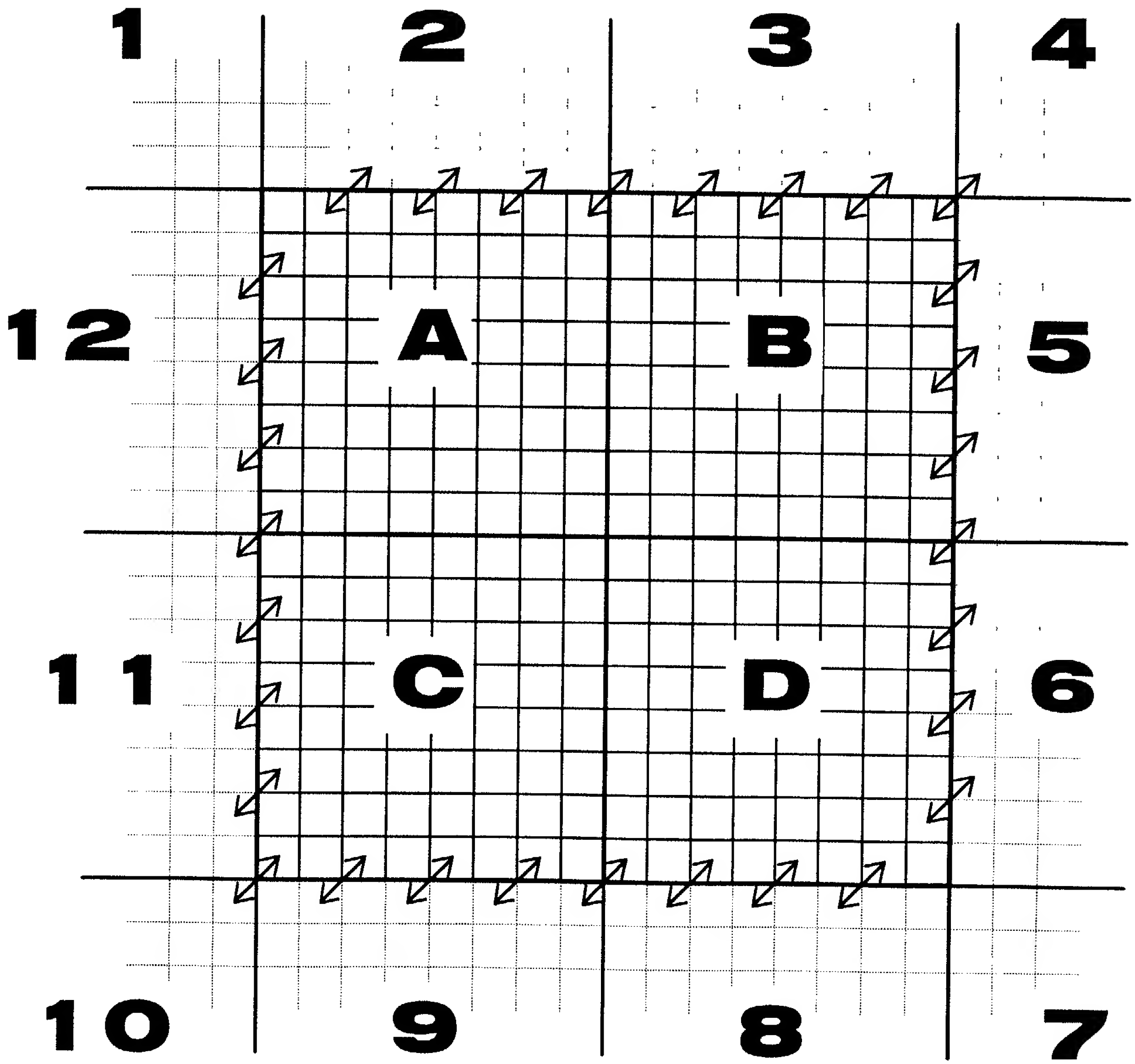
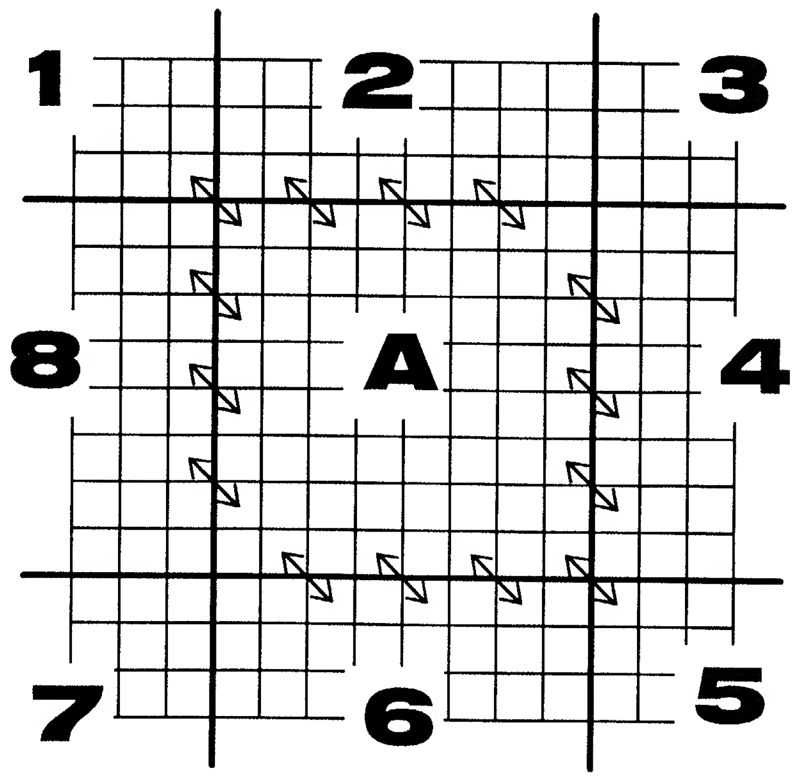


FIG. 2(a)



HASKELL 59-24-9

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am an original, first and joint inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **VIDEO CODER EMPLOYING PIXEL TRANSPOSITION** the specification of which was filed on February 14, 1997, as application Serial No. 60/038,017.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

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